GEH-527C

INSTRUCTIONS

VERTICAL WATERWHEEL-DRIVEN GENERATORS

GENERAL ELECTRIC
SCHENECTADY, N.Y.

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VERTICAL WATERWHEEL-DRIVEN GENERATORS

UNPACKING

A generator which is not to be installed immediately should be stored in a clean and dry place, protected from low temperature and sudden changes in temperature or humidity, and not unpacked until everything is ready for installation. Machined parts are slushed before shipment to prevent rusting; however, the equipment should be examined carefully on arrival at destination and any rust or moisture removed, and surfaces reslushed where necessary. Rust once started will continue if the surfaces are reslushed without first removing all signs of rust and moisture. Special attention should be given to the shaft journal surfaces to prevent rusting and pitting. Machines held in storage must be examined at frequent intervals, and reslushed when necessary. The slushing compound can be removed readily by using commercial benzol and kerosene in the proportion of one to one.*

Do not use sandpaper or any abrasive or metallic scrapers to clean finished surfaces. After the shaft and bore have been thoroughly cleaned, carefully remove with a fine file or scraper any burrs or bumps received in shipping.

If the coils of the machine have been exposed to a low temperature, do not remove their coverings until they have had sufficient time to attain a temperature nearly as high as that of the room in which they are to be unpacked and located; otherwise, when open, they will sweat.

During storage, the windings should be protected from sweating and freezing by some safe and reliable heating system which will keep the temperature of the machine slightly above room temperature. An electric heater with thermostatic control is recommended.

Machines should be handled carefully to prevent damage to the windings and other parts. In the case of heavy machines in stations not equipped with traveling cranes it is well to build a crib or horse of heavy timber for handling the machine. The only proper method of supporting a rotor while either moving or stationary with the shaft in a horizontal position is by slings or blocking under the shaft or by a padded cradle under the poles. With the shaft in the vertical position, the rotor may be lifted by slings through the rotor or by a lifting trunnion such as shown in Fig. 1. The trunnion fits on the shaft in the place normally occupied by the thrust collar and is held in position by means of a circular key which fits in a groove in the shaft.

The tapped holes in the end of the shaft must not be used for lifting. These holes are used for attaching the direct-connected exciter or for jack bolts for assembling or removing the exciter armature.

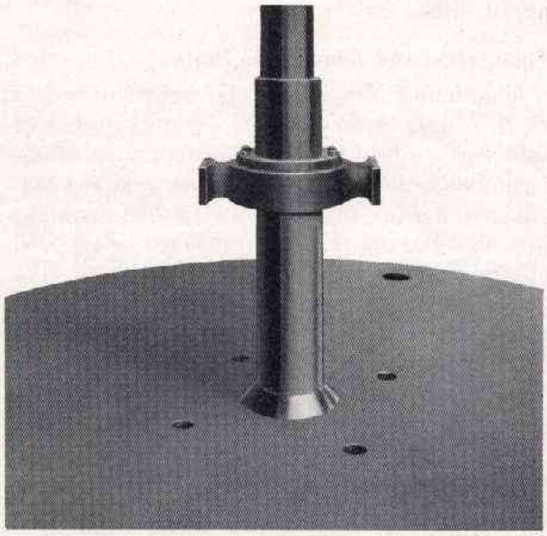

Fig. 1. Lifting Device for Revolving Field for Vertical A-c Waterwheel Generators

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*NOTE: In using benzol-kerosene mixtures care must be taken to avoid fire, as they are very volatile and the gas is explosive when mixed with air. Benzol, carbon tetrachloride, and other solvent vapors are toxic to some persons; they are heavier than air and therefore should be used with proper ventilation or out in the open.

INSTALLATION

Machines should be installed where they will be protected from moisture, escaping steam, drip from pipes, and any acid, alkali, oil, or gas; also dust, dirt, lint, or other injurious substances.

The windings should be protected during assembly against mechanical injury and to prevent metal chips or other foreign materials from falling between the coils; both the windings and the core ducts should be covered to keep out cement dust.

Ventilating Ducts

If the machine is designed to take in air from the pit, suitable ducts must be provided in the foundation. The generator outline print shows the approximate size of the pit, and information for determining the size of air ducts. The ducts should be as short and straight as possible.

With machines which discharge the cooling air into the station, provision should be made not only for proper openings in the foundations for entering air but also for adequate fixed discharge openings out of the station.

In cases where a totally enclosed system with surface air coolers is used, separate instructions are furnished for the coolers.

Foundation and Foundation Bolts

The foundation should be substantial and rigid, of reinforced concrete, or steel girders of sufficient stiffness to insure freedom from vibration. It should be designed to support the machine frame (as shown in the outline drawing) in such a manner that the frame will be relieved of strains.

The foundation bolts should be located accurately with a template. In the case of small or medium-size machines where the foundations are relatively massive and the stresses due to shocks from system disturbances are low, a slight variation in the position of these bolts may be provided for by locating them in iron pipes whose inside diameter is at least 1 in. larger and preferably 2 in. larger than the diameter of the bolts. These pipes are to be filled when grouting the foundation caps. If a stud is used, the lower nut should be riveted or tack-welded to prevent its turning when tightening the upper nut.

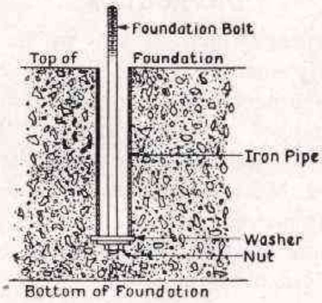

Fig. 2. Method of Locating Foundation Bolts

Probably the easiest and safest method of installing foundation bolts is to leave pockets for them in the concrete foundation. These should be rectangular and somewhat larger at the bottom than at the top. The opening should be large enough to take the bolt with the bottom washer and nut in place. The bolts are hung in the foundation caps while these are leveled, and the holes filled when the foundation caps are grouted. In some cases the holes are partially filled with grout when the foundation caps are roughly located, so that the bolts may hold the foundation caps securely after the final setting is made; this prevents accidental shifting while grouting.

Single-tapered wedges should not be used to support the foundation caps when grouting. The caps should be supported either with flat plates with shims, by double parallel-tapered wedges, or by leveling screws and plates when they are provided.

The holding-down bolts of the brackets may be used for jacking when leveling and installing shims, by using the tapped holes that are provided. After the generator has been leveled and lined up, horizontal radial dowel holes are drilled between the frame and foundation caps. Provision should be made for space for an air drill for doing this drilling.

Assembly and Alignment

The method of assembling machines will vary depending on the size, type of construction, and the location of the thrust bearing.

Small machines shipped completely assembled may be lifted into place with the foundation caps bolted to the bottom of the frame or base ring and adjusted to the level and vertical alignment of the waterwheel coupling by jacking radially and by shimming under the foundation caps. Such machines after aligning should have the bearings removed, cleaned, and inspected, and the gaskets coated with No. 1201 G-E Compound before putting the machine in service.

On machines that are shipped disassembled, care should be taken that the proper part for each machine and each location be used, that the numbers of the pieces agree and that the assembly marks match.

For machines which have the lower guide-bearing bracket integral or bolted to the stator frame, the frame and lower bracket may be lifted into place with the foundation caps bolted to the bottom of the frame, setting the frame at the level called for on the outline. The holding-down bolts should be centered in the holes in the stator frame to give clearance for final centering. When establishing stator-frame levels, measurements from the top of the frame should be used. The rotor and shaft are lowered into the frame until the rotor rim rests on the brake-supporting blocks and centered until the air gap is approximately uniform. The upper bracket can then be assembled. If the stator frame has been drilled for the bracket dowel holes, the dowels should be installed. The thrust bearing is assembled, and, after lifting or jacking up the rotor split-ring key above the thrust collar, bolted in place. The upper and lower guide bearings and oil pan can then be assembled. After checking to see that the air gap is uniform, the machine may be levelled and aligned to meet the waterwheel coupling by jacking the generator as a unit. If the frame has not been drilled for the thrust-bearing-bracket dowels, the bracket with bearings in place should be moved radially until the air gap is uniform before dowelling.

When the lower guide-bearing bracket is separate from the frame or base ring (see Fig. 3) the same procedure can be followed, but in such cases the lower bracket and frame are set independently at the levels called for on the outline and the bracket and frame centered above the waterwheel coupling by means of a plumb bob. After the coupling bolts have been installed the lower bracket is shifted to give uniform radial clearance in the guide bearing before dowelling.

When the thrust bearing is below the rotor (see Fig. 4) the lower bracket may be installed first, centered above the waterwheel shaft by means of plumb bob, and shimmed to approximately the elevation shown on the outline. The shaft, thrust bearing, and lower guide bearing may then be assembled, and the shaft coupled to the waterwheel shaft. In most cases, however, the lower bracket is lowered in place with the shaft, thrust bearing, and guide bearing assembled. The lower bracket is levelled and adjusted radially until the clearances in the guide bearing are uniform with the shaft true vertically. The stator is located at approximately the correct elevation shown on the outline and centered radially, using a tram from the shaft to the stator core. The rotor is lowered in place and the lower bracket relevelled to keep the shaft vertical and the coupling joint at the proper elevation to allow for the additional deflection of the bracket due to water thrust. The stator frame is adjusted so that the poles will be central with respect to the stator core when load is on and so that the air gap is uniform. Foundation caps for the lower bracket and stator frame are grouted, and, after rechecking alignment and air gap, dowelled. The upper bracket can then be installed and centered. The upper guide bearing, if there is one, should be checked for uniform clearances. The upper bracket is then dowelled. One type of thrust-bearing bracket consists of two main parallel girders which carry the thrust load. Some of these brackets have side-arm girders for radial support. When assembling these brackets the thickness of shims between the side arm and the foundation cap should be

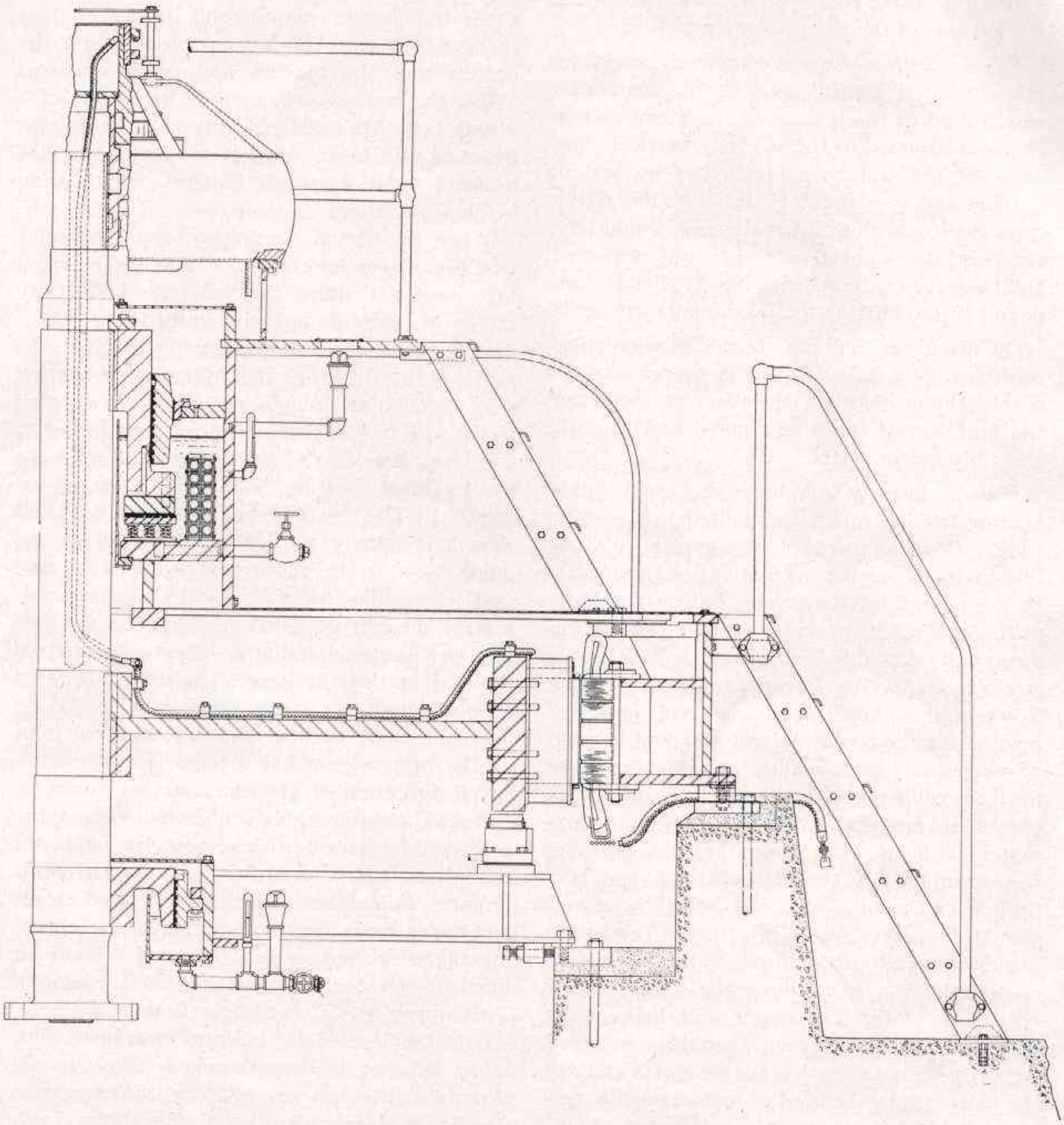

Fig. 3. Sectional View of Small Waterwheel-driven Generator with Combined Upper Guide and Thrust Bearing and Self-oiling Lower Guide Bearing

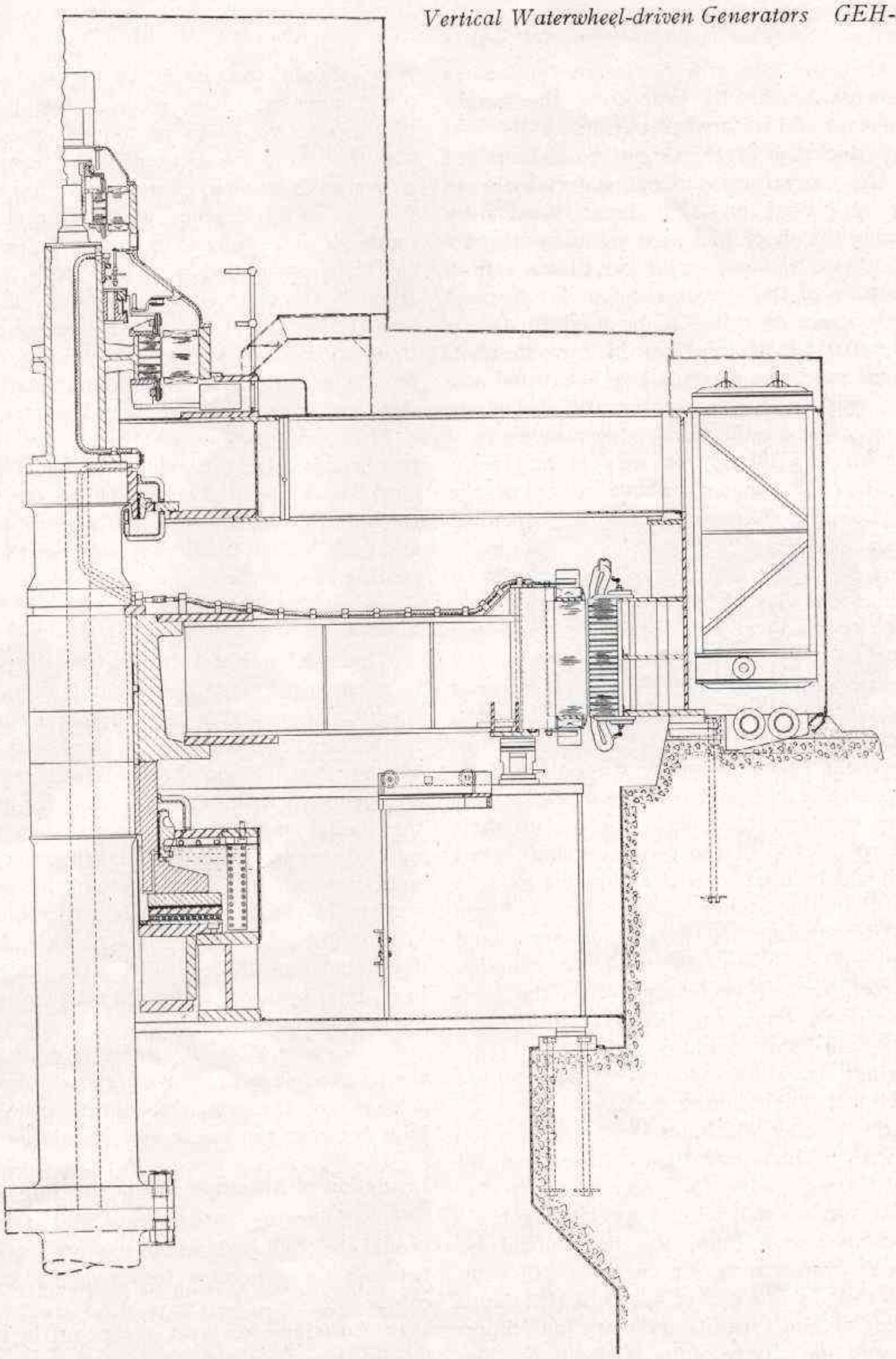

Fig. 4. Sectional View of Large Waterwheel Generator with Combined Guide and Thrust Bearing Below the Rotor and Self-oiling Upper Guide Bearing

such that the side arm carries no load when the thrust bracket is supporting the weight of the rotor and waterwheel runner.

The thickness of shims can be determined after the generator rotor and waterwheels are being supported on the thrust bearing by removing the chock blocks or shims from under the side arm and measuring the distance from the bottom of the arm to the foundation caps. The thickness of shims to be used should be 15 mils (0.015 inch) less than this measurement. On some machines the side arm is pivoted and free to swing with the main bracket deflection. In such cases no adjustment is necessary.

The air gap should not vary at any point more than 12 per cent above or below the average air gap shown on the outline drawing. The air gap should be parallel from top to bottom. In taking the air gap, particularly on machines with amortisseur winding, care should be used to read values from iron to iron and at the center of the pole.

In some cases the end ring of the amortisseur winding projects above the top of the pole. In such cases a small block attached to a wire can be held over the top of the pole and an air gap gage placed on top of the block.

When exciters are mounted on a stub shaft bolted to the top of the generator shaft, great care should be used when making this joint to insure that the exciter commutator will run true. After starting up, the commutator should be checked for eccentricity and the coupling joint corrected, if necessary. When the commutator runs true, the bolts attaching stub shaft to main shaft should be locked.

Bearings should be kept covered with canvas as much as possible during the assembly.

On the smaller machines, levelling may be done with a high-grade spirit level and an accurate straight edge. On larger machines it is better to use a wye-level and special target.

In using plumb lines, the line should be protected from strong air currents. Allowing the bob to hang in a pail of heavy oil will damp the swinging and expedite the work materially. The plumb line may be of fine oiled-silk fish line on small machines, but a steel wire and a heavy bob should be used on large machines.

On large machines, records should be made of the relative levels of foundation caps and also the top of the sections of the frame as well as vertical alignment charts and values of air gap for use as a reference when later checks are made for any evidence of foundation settling.

Before assembling bolts and studs, especially those in the stator-frame joints of split stators and at the hub of radial-arm bearing brackets, they should be heated by placing them in boiling water for a period equivalent to five minutes for each inch of their diameter.

After the machine is levelled and lined up, the brakes should be shimmed to bring them level and at such a height that, after jacking, the brake blocks will support the rotor uniformly and high enough to allow removal of the thrust-bearing runner plate.

Stators

When lifting stator frames the slings should be so arranged that the weight is supported by the lifting bars and not by the spacer bars inside the frame. Frames should be level so that there will be no distortion. Large-diameter machines are furnished with push-pull jacks for adjusting the radial position and correcting possible radial distortion of the frame. When the frame is split, care should be taken that the adjoining sections of the core are flush both radially and horizontally. On larger machines, additional dowel holes must be drilled after the frame is in its final position, using the pilot holes drilled in the joint bars.

In all cases after the frame is adjusted and the foundation caps grouted, radial dowel holes as shown on the outline should be drilled at the joint between the frame and foundation cap.

Insulation of Armature Leads and Joints

The following instructions and tabulation should be followed when making connection between the generator terminals and the line cables.

1. Starting each layer of tape at the bottom, insulate the terminals and joints with tapings one-half lapped of 0.012-in. varnished cloth tape

applied with varnish to seal all the interstices. The following table specifies the minimum number of tapings which should be applied for machines of various voltages.

2. Apply one layer of 0.012-in. stay binding one-half lapped, and over this five coats of moisture-proof varnish.

3. Do not support more than five feet of station cables on the generator terminals.

Voltage	Tapings of Varnished Cloth Tape for Terminal and Class A Coil Leads	Tapings of Mica Tape for Class B (Mica) Coil Leads
0–1000	2	3
1001–3000	2	4
3001–5000	3	6
5001–7000	4	7
7001–9000	5	9
9001–11000	6	11
11001–13000	7	13
13001–14000	8	15

Machines having the stator shipped in more than one section require installing and connecting of the coils at the split. Mica-insulated coils should be heated to 70 C by thermometer using a heating current value which will heat the coil in not less than 45 minutes before installing. Small coils can be heated in an 80 C oven. Connections should be made in accordance with the connection diagram furnished with the instruction book. For machines having Class B insulation the coil connections should be given the number of mica tapings shown in the table. For other machines, varnished-cloth tapings as shown in the table should be used. When taping the connections, break the joint by lapping half the joint insulations over the coil lead insulation down to the point where the lead leaves the coil. A similar length of overlap should be used on the pole leads.

Grounding

Ground the frame to protect the operator in the event of the insulation becoming punctured. The ground connection must be heavy enough to carry safely the short-circuit current in case of an armature ground.

ROTORS

Laminated Rim Rotors

The following is the preferred method assembling laminated rims when installing. The rotors should be levelled carefully on a foundation heavy enough to carry the complete weight without appreciable settlement. The brakeplates should be bolted to the rotor arms, and blocking for supporting the outer side of the rim punchings should be installed level with the top of the brakeplate. Substantial blocking should be used not only below the rim punchings but also under the ends of the rotor arms and brakeplates, so that there will be no shifting as the rotor laminations are placed; see Fig. 5. The rotors and blocking should be levelled very carefully with a wye-level and special target, and checks should be made from time to time to insure that the rim is assembled in a horizontal plane, at right angles to the bore.

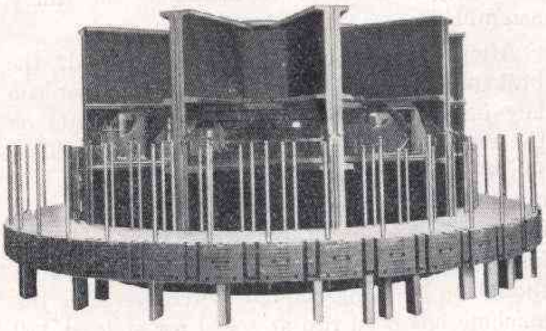

Fig. 5. **Blocking for Rim Punching Assembly**

Before starting assembly, the laminations should be sorted by weight into piles, each pile varying by not more than 2 lb, and the piles used in turn in assembling complete rings around the rotor. This will insure even distribution of weight in the rim.

The large keys should be placed in the slots in the end of the rotor arms and locked out far enough so that there is room for inserting the driving keys after the stacking is completed, but with enough clearance between the face of these keys and the bottom of the keyway in the rim laminations so that the punchings can be assembled easily over the keys. Temporary shims should be placed between the ends of the rotor arms and the inside of the rim punchings to center accurately the rim on the rotor.

Sufficient plates are stacked on assembly pins to support the studs in a vertical position. The studs are then dropped into position in place of the assembly pins and the rest of the rim assembled by dropping the punchings over the studs.

Each layer of laminations should be seated on the previous layer by tapping with a heavy mallet. The laminations should be pressed at intervals of 12 to 16 inches as the rim is assembled.

After the rim stacking is completed, the brakeplates are dropped off and the inner rim key installed but not tightened. The nuts on the studs are then tightened and tack welded. Drive the rim keys evenly to prevent distortion of the rim, and maintain uniform clearance between the ends of the rotor arms and the inside of the rim punchings. The rim keys should be left long enough to redrive after the machine has been run at speed for at least 150 hours or after any overspeed tests are completed.

Assembly of Solid Rotors on Shafts

Check carefully the bore and shaft against each other. If there is any question, obtain the pressing allowances. Also check the keys against the keyways both for height and width. Adequate pressing equipment must be provided. The particular type will depend on local facilities, design of equipment, press-fit allowances, etc.

Some rotors have slide fits and slide into position on the shaft due to their own weight. Pressing equipment should be available even for such cases, however, for if the hub is allowed to stand for any length of time during assembly, two or three times more pressure may be required to start it again than required to keep it moving.

The lubricant recommended for use when pressing a rotor on its shaft is either very fine graphite mixed with petroleum machine oil, or pure vaseline. Do not use white lead or any vegetable or animal oil, as they may start corrosion.

Wherever possible, rotors should be heated to facilitate pressing them on the shafts. Laminated rotors and parts with heavy pressing allowances must always be heated. The best method is to use an oven heated by electric units or steam coils. It is necessary that the complete rotor be heated slowly and evenly to prevent distortion or damage. An oven temperature of 90 C can be held on wound rotors or fields having pole windings in place. Rotors or flywheels without electrical windings can be heated in an oven temperature of 125 C. Arrangements should be made so that the expansion of the bore can be checked from time to time with a pin gage or an inside micrometer. This gage should be kept lying on the shaft between readings so that it will be at shaft temperature when used to check the bore. Expansion will be approximately one mil per inch of bore diameter per 100 C rise. Temperatures under 100 C will therefore give ample expansion in the majority of cases.

Never apply direct heat by flame to any metal part of the rotor being heated.

If the rotor is made of more than one section, the sections should be assembled and lined up when cold, in the oven. After heating to the required temperature the oven is removed without disturbing the rotor and the shaft lowered into the rotor. An alternative method is to shrink on one section at a time, allowing each section to reach room temperature before the next is shrunk on. In all cases the bore should expand enough so that they can be slid, dropped, or bumped into place with a battering ram; however, the shaft and heated part tend to equalize these temperatures quickly, and arrangements should therefore be made to have pressing equipment available in case of emergency. The parts must be gotten together properly before the temperature equalizes and the parts seize. Substantial keys must be driven in at least two pole-key slots to align and hold the sections together.

Shrink Links for Split Revolving Field Rims

A pin gage should be made 18 to 20 mils longer than the distance between the shoulders of the shrink link or key when cold. The links will expand one mil per inch of length for each 100-degree rise. Before heating the keys the two sections of the rim should be brought metal-to-metal with temporary bolts or clamps and lined up properly. The links should then be heated slowly and uniformly until the gage will enter freely in the space between the shoulders. The gage should be kept lying on the field rim when not actually in use. This will insure the gage being at the same temperature as the rim and will avoid any errors from the expansion of the gage from heating.

The links must not be heated over 300 to 350 C.

Location of Rotors or Flywheels on the Shaft

Special care must be used when pressing or shrinking armatures, rotors, or flywheels on their shafts, to locate them accurately. This applies to machines that are made without a definite shoulder or circular keyway to fix the location of the hub.

The face of the coupling or the oil collars should be used to measure from, and the other point should be the center of the pole pieces on a revolving field, or the center of a flywheel face.

Assembling Field Poles

The poles must be located so the centers of all the poles, which are usually shown by a prick-punch mark, are in the same plane and this plane must be at right angles to the shaft. The elevation of this plane should be such that when the rotor is assembled the centers of the poles will line up with the center of the stator core. Either a tram mounted on the shaft or a wye-level should be used to locate the centers. Do not use the brakeplates or the end of the rotor as a reference point, because these parts may vary considerably.

When assembling the pole, iron-to-iron contact should be obtained for the full length of the pole base.

Keyed poles should be assembled carefully in accordance with the factory markings on the poles, rotor body, and the pole keys. After the level of the pole has been established, stop blocks should be welded in the keyway at the bottom of the pole to prevent the pole from slipping down in case the keys become loose.

The keys should be checked for tightness after the machine has operated a short time and the keys redriven if necessary until they are tight. Ordinarily, two or three drivings will insure the keys' staying tight, but they should be checked regularly. When overspeed test is to be made the keys should be left long enough to permit redriving after the test. Bolted poles should be checked for tightness after the machine has run a short time.

THRUST BEARINGS

The thrust bearing consists of a grooved, stationary, babbitted plate and a grooved rotating steel or cast-iron surface which is either a separate plate or (on smaller machines) part of a thrust collar. In both cases the runner is supported rigidly on the shaft by the thrust collar. The stationary babbitted plate is mounted on a number of precompressed springs. This stationary plate is prevented from turning by means of dowels located in a base ring.

Because of the heavy loads on vertical thrust bearings the runner plates are given a high degree of finish and the babbitt surfaces are machined carefully.

When unpacking, handling, or storing these parts, care should be exercised to prevent injury to this finish by rust or mechanical damage.

Unpacking and Storing

Do not unpack the bearing unless there is evidence of damage to the boxing, but store it in a clean, dry location and see that it is supported properly to prevent distortion. Just before the bearing is to be used, uncrate it and remove the slushing compound with kerosene or gasoline, using clean lint-free rags and wood scrapers. Any rusty or injured spots on the rubbing surface of the runner plate should be smoothed, using a fine oilstone and kerosene. Special attention should be given to removing scratches in the radial direction; such scratches should be removed by stoning in the circumferential direction. Do not stone the runner surface in a radial direction at any time.

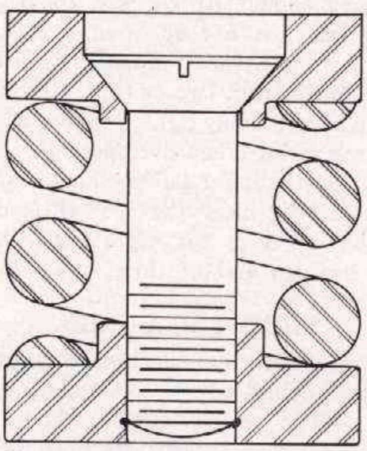

Fig. 6. Individual Spring, Showing Method of Precompression

Installation

When installing the bearing be absolutely sure that all parts of the bearing and the bearing housing are free from dirt and lint. Assemble the oil-well tube with the gasket, coated with No. 1201 G-E Compound. Test this joint by partially filling the housing with kerosene and allowing to stand for 24 hours. Some machines have insulation below the bearing; in such cases first install this insulating washer and then the spring plate. Larger machines have a separate base ring; for these cases the base ring should be installed and lined up by dowel pins and then the springs (see Fig. 6) assembled. Place the babbitted stationary plate on the springs and note that the dowel pins enter its lower side properly and have ample clearance from the top of the plate. Then the stationary plate should be covered with vaseline, graphite grease (Gredag 81½), or heavy lubricating oil.

For machines having the thrust bearing above the rotor the runner plate can then be lowered until it rests on the stationary plate. After the thrust collar is mounted on the shaft the runner plate can be turned until the dowels line up with the holes in the runner by using cap bolts screwed into the tapped holes in the side of the runner plate. When assembling the split ring on top of the thrust collar, check to see that there are no burrs or bumps in the joint and that the ring seats solidly on the top of the thrust collar.

For smaller machines having the thrust bearing below the rotor the two halves of the runner plate can be slid onto the top of the babbitt plate and then turned until the dowel holes and pins line up.

With the larger bearings the stationary plate may be slid into place by using a temporary steel shim on top of the springs. After the shim has been removed the stationary plate-retaining block can be bolted in place.

Various methods are used for assembly of the larger runner plates depending on the construction and clearance space available. The runner may be slid in directly on the babbitt plate or the runner may be slid in on copper strips placed on top of the babbitt plate, removing the copper strips when the plate is in place by jacking up the runner plate. In such cases the runner must be kept level with the babbitt plate all through the sliding operation and a thick coat of lubricant applied to the surface before assembling. Another method is to slide the babbitt plate into position with the runner mounted on top of the babbitt plate. Fig. 7 shows the skids and the shims which extend over

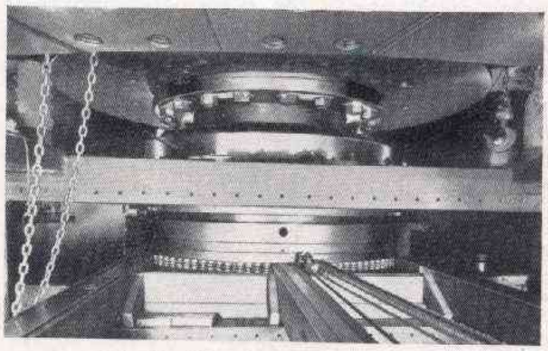

Fig. 7. Showing Skids and Shim

the springs for this method of assembly or disassembly. A third method is to insert studs in the tapped holes provided in the sides of the runner plates and slide these studs on skids placed in the housing and the plate jacked up against the thrust collar until after the stationary plate is assembled. Carriages for installing the babbitt and stationary plates are provided for some machines.

Bearing temperature bulbs should be installed, fastened in place, and the leads brought out so that they clear the runner and, in the case of insulated bearings, so that they do not ground the bearing. The leads should also be supported properly to prevent movement resulting from rotation of the oil.

The piping to the oil coolers can then be completed and a check made for leaks.

The bearing should be filled with lubricating oil to prevent rusting during the period required to finish the assembly of the generator.

Oil

It is very essential that only a first-class lubricating oil be used. Oil should be purchased directly from oil manufacturers of recognized standing who will assume the responsibility for the selection of the best oil for the service. Experience has shown that, in general, the viscosity of the oil at a temperature of 100 F should not be less than 200 seconds or much over 300 seconds, as determined by the Saybolt Universal Viscosimeter.

Guide Bearings

Guide bearings usually are furnished split in two or more sections which can be fitted around the shaft, and after the joint bolts are assembled, slipped into the seat and bolted in place. After the bearing temperature bulbs have been installed the oil pans or oil-vapor seal ring can be bolted in place. If a seal ring is used check the clearances to avoid any possibility of rubbing. Guide bearings in most cases are lubricated by means of spiral grooves cut in the face of the guide bearing journal. See Fig. 8.

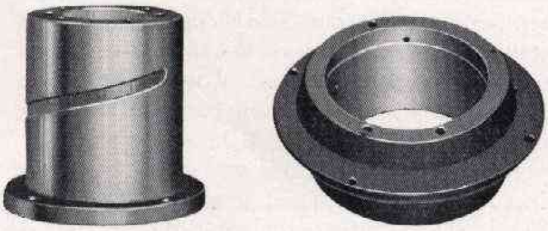

Fig. 8. Thrust Collar and Guide Bearing, Showing Oil Grooves

Starting

In the case of bearings connected to a station oiling system make sure that the specified amount of oil is being circulated through the bearing housing. The temperature of the ingoing oil after steady conditions are obtained should not exceed 35 C and the amount should be such that the difference between the ingoing and outgoing oil will be between 10 and 20 C. The guide bearings will require approximately one quart per minute for machines less than 1000 kva and 3 or 4 quarts for larger machines.

On machines without external oil-circulating systems, but with coolers, turn on the cooling water and regulate the flow after steady conditions are obtained, until there is 10 to 15 C rise through the cooling coil.

For the first start, the machine should be run at ⅓ speed for a half hour, noting temperatures at one-minute intervals for the first ten minutes. Any injury to the rubbing surfaces will be indicated by a rapid rise of the oil temperatures in the housing. Usually a temperature rise at the rate of 1 degree per minute indicates cutting, and the bearing should be taken apart for examination. Five minutes is sufficient to determine the rate of rise, and if any cutting occurs during this time and at low speed the bearing will not be injured seriously.

When the performance of a bearing is being indicated by a temperature detector located in the bearing metal the temperature rise will be very much faster than the rise of oil temperature. However, if the babbitt is being wiped the temperature will continue on to 100 C.

If the babbitt is dragged, remove the loose metal and stone any scratches in the runner with a fine oil stone and kerosene and carefully scrape any high spots in the babbitt plate. In scraping the surface of the babbitt, remove only a very small amount of metal at a time. Remove any grit or metallic particles imbedded in the babbitt at the end of the scored marks.

If the bearing operates well at ⅓ speed the speed may be increased gradually to normal speed. The bearing temperatures should be watched carefully during the first few starts after the machine has been put in service. On small machines the oil-bath temperatures with steady conditions may reach 70 C, but on larger machines the cooling system is usually designed to give oil-bath temperatures of 50 C or less.

Rebabbitting Bearings

Where circumstances are such that a bearing has to be rebabbitted in the field, the following instructions will be of value.

Before melting out the old babbitt, take particular note of the oil grooves and holes and the bevelling, making a sketch, if necessary, so that these features can be duplicated.

When melting out the old babbitt (if a gas torch is used) stand the bearing on end and apply the flame on the babbitt, beginning at the top. Remove thoroughly all of the old babbitt. Carefully remove, by burning, all oil, dirt, or any other foreign matter from the inside of the shell before rebabbitting. Continue the burning until all smoke ceases, showing that the oil and dirt have been burned off; then scrape the surface with a file or other scraping tool and rub it down with coarse sandpaper, to remove all scale and oxide. Insert wooden or asbestos plugs in the oil-supply holes to prevent filling with babbitt.

Preheat the casting (or steel ring) and mold to a temperature of about 100 C (212 F). If a thermometer is not available, a few drops of water on the casting will indicate the proper heat by sputtering violently.

If the shell is heated too hot, the length of time for cooling may be so prolonged that the heavier metals in the babbitt will have time to settle to the bottom end of the bearings, in which case the metal in the one end of the bearing will be soft and in the other end brittle, whereas if the shell is too cold it will cool the babbitt too suddenly and cause it to shrink away from the shell. For rebabbitting bearings use G-E Alloy B21A1. Do not use the old babbitt removed from the shell. Heat the babbitt to a temperature of about 475 C (887 F). This temperature can be checked roughly by running a small clean pine stick into the molten babbitt. The stick will ignite at about 475 C. Stir the metal thoroughly at frequent intervals; otherwise the heavy metals will settle to the bottom of the pot.

Keep the babbitt metal covered with charcoal or graphite to prevent oxidation.

Mix the babbitt thoroughly and purge with resin or salammoniac to remove all foreign substances. The top should then be skimmed off.

For the guide bearing, select a mandrel which will allow about ¼ in. on a side for finishing. Set the shell on end with a little fire clay or sheet of asbestos underneath. Use clamps or a weight to hold the shell and mandrel in place.

Pour the metal smoothly and as quickly as possible. See that the lip of the ladle is free from burrs or other surface irregularities in order to pour a smooth, round stream. Splashing of the metal will produce blowholes and give a mushy bearing. **Never pour babbitt into a shell that contains any water or is not perfectly dry.** Serious burns have resulted from a failure to observe this rule.

When the shell is filled up to the top, tamp the babbitt down with a wooden stick that will pass between the mandrel and the shell. This will remove any blowholes that may have formed. Do this quickly before the babbitt is set, and keep the casting filled.

Let it stand 15 to 20 minutes and then remove the mandrel. In chucking the bearing in a lathe or boring mill be very careful not to distort the bearing shell from a true cylinder. Bore the babbitt to the proper diameter and chip the oil grooves. It is not necessary to scrape the surface of the babbitt before putting the bearing in service.

Fig. 9 shows a stationary ring for a thrust bearing ready for pouring of the babbitt. The ring is on a larger plate and a steel band is clamped tightly around the outside. Pieces of rectangular steel key stock are placed in the position of the radial oil grooves. Each piece is fastened to the ring to be babbitted by two small screws not over ¼ in. diameter. Place one key at the radial slot in the steel plate. The use of these keys is to reduce the warping of the ring due to the shrinkage of the babbitt as it cools. By braking up the continuous ring of babbitt into segments, the distortion of the ring is reduced to a minimum. Pour the babbitt quickly in the center of the ring, letting the hot metal spread out over the plate to a depth of ½ to 1 in. Continue to feed a little hot babbitt at the center as the metal solidifies on the steel ring. When cool, machine off all excess babbitt, leaving the thickness of this ring about ⅛ in. more than the finished dimension. Then turn the ring over and true up the bottom side, and finally finish the babbitt surface, taking very light cuts with a sharp tool to obtain as smooth a surface as possible. The keys in the oil grooves can be removed by driving a cold chisel under them and breaking the small screws.

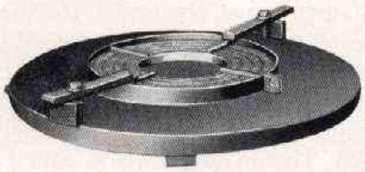

Fig. 9. Stationary Bearing Ring Arranged for Pouring the Babbitt Face

Machine the oil grooves to the correct size if the keys used were smaller than the original grooves, and bevel the sides so there will be no sharp edges coming in contact with the runner where the oil is drawn between the rubbing surfaces. Do not hand scrape the babbitt to fit the rotating ring or a surface plate before the repaired part is put in service, but follow the instructions previously given in connection with the starting of new bearings.

BRUSH RIGGING AND COLLECTORS

To insure uniform wear of the collector rings, adjust the brushholders on the studs so that the brushes will be staggered across the width of the collector rings. See that the brushes move freely in the holders and at the same time make firm and even contact with the collector rings. Poor contact will cause sparking. Brushholders should be set ⅛ in. from the rings.

The pressure of the brush against the ring is obtained by compression of a helical spring bearing against the back of the brush (see Fig. 10). The spring is held compressed by a fulcrum which can be set in various positions along the slide bar of the brushholder. To the end of the fulcrum which bears against the brush is attached a metal button and measuring pin, which projects through the fulcrum when the spring is compressed. The measuring pin is marked with rolled projections so that the brush pressure can be observed easily by counting the number of projections on the measuring pin above the fulcrum. The first projection of the measuring pin corresponds to 1½ pounds pressure and each additional notch to an increase of ½-pound pressure. The pressure should be adjusted to two pounds or two projections above the fulcrum.

To obtain a final brush fit, so that the curvature of the brush conforms to the curvature of

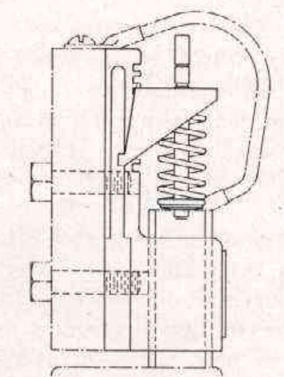

Fig. 10. Typical Brushholder

the ring, use sandpaper with the sanded side up, drawing it in the direction of rotation on the ring surface. Lift the brush when moving the paper back to its original position. Keep the ends of the sandpaper close to the collector ring to avoid rounding the edges of the brush. Treat each brush separately in like manner. See that the pigtails do not interfere with the rigging.

A collector eccentricity of 1/32 in. does no harm on low-speed machines. The brushes can follow the rings readily at these low speeds and the movement tends to keep them free in their holders.

Where operating conditions are severe, collector-ring surfaces can at times be kept in better condition by occasionally changing polarity of the brushes. Leads to the collector brushes or at the switchboard should be made long enough to make possible this reversal of polarity.

In some cases, field temperature recorders are used. If the field leads are reversed at the field switch no changes in recorder connections are necessary. However, if the field leads are reversed at the machine the voltage leads to the recorder should be reversed.

Two types of collectors rings are used.

1. ***Shrunk on***

This type of collector consists of steel or alloy rings shrunk on a mica-covered cast-iron sleeve, which is tapped or pressed on the generator or exciter shaft.

2. ***Bolted to Shell***

Split or solid cast-iron, steel-plate, or alloy rings are mounted by mycalex insulators to a cast-iron sleeve which fits the shaft.

BRAKES

The function of brakes on vertical-shaft generators is to bring the machine to rest in a reasonable length of time varying from 3 to 5 minutes after the turbine gates have been closed, and to hold the rotor at rest against a small amount of leakage of water through the gates. Windage and bearing friction will stop some machines without brakes, while others will continue to run slowly due to the leakage of water through the turbine gates.

Brakes are not designed to be applied during a runaway or for application at full speed. When stopping a generator keep the field excited and use the brakes as little as possible by allowing the bearing friction and windage to reduce the speed. Under normal conditions the generator should be allowed to come down to ½ or ⅓ speed before using the brakes. Begin with about 50 pounds per square inch air pressure at half speed, increasing to 100 pounds per square inch at ¼ speed. The pressure may be raised gradually as the speed reduces. The maximum pressure used should be 125 pounds per square inch. Do not apply the brakes at full speed.

When the generator is to be stopped, and is to be left unattended, lock the waterwheel gates so that the waterwheel cannot start up and run against the brakes.

Combined Brakes and Jacks

When brakes are used as jacks to raise the rotor, oil or water is pumped into the brakes at a pressure of 1000 to 1500 pounds per square inch by a hand-operated plunger pump. By means of a three-way valve the brakes are connected either to the air supply for braking or to the high-pressure pump for jacking. When the rotor has been raised, steel blocks furnished as part of the brake are placed between the brake support and the braking surface to support the weight and eliminate the necessity of maintaining the oil or water pressure continuously.

OIL PIPING

The oiling system for vertical generators must be installed very carefully. Every length of pipe should be reamed at the ends and blown out with compressed air or steam before being connected. Rap the pipe smartly with a rawhide or wooden mallet while blowing out to dislodge any scale or chips.

Use No. 1201 Compound on all joints and flush the complete piping with oil before placing in service. If the generator is lubricated by a station oiling system, pump the oil through the

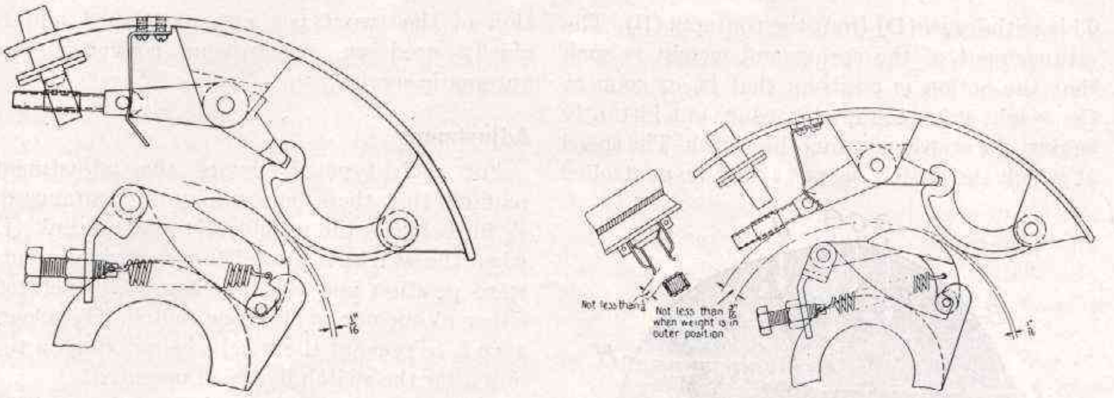

Fig. 11. Circuit-opening Device

piping several times as a further safeguard against abrasives getting in the bearings. Fasten a piece of cheesecloth over the end of the ingoing oil pipe and circulate oil through the bearing housing for several hours before starting the generator to remove any scale and dirt from the piping system. If considerable dirt is collected, continue to use this cloth strainer for several days until all dirt is removed from the system.

BEARING INSULATION

Where the bearings are insulated to prevent the circulation of shaft currents it is necessary to use insulated sections in any piping connected to the oil reservoir. The location of insulated joints is shown in the outline drawing. When all the piping is installed the insulated joints should be tested by connecting a 25- or 40-watt lamp in series with the joint, using a 125-volt source of voltage supply. With double-insulated joints the effectiveness of the insulation can be checked with the machine completely assembled. To check single-insulated joints it is necessary to separate the coupling, remove the guide bearings, and lift the rotor off the thrust bearing. A megger gives misleading results and is not satisfactory for testing bearing insulation.

TYPE B SPEED-LIMIT DEVICE

Speed-limit devices may be circuit opening, circuit closing, or both circuit opening and circuit closing. They are for use with synchronous converters, motor-generator sets, or other apparatus, to prevent excessive speeds.

The speed-limit device should be tested at regular periods, as well as at the time of installation. It is designed to operate at 15 per cent above normal speed. The device should be tested by gradually increasing the speed to a point at which the speed limit should operate, as noted by a tachometer held against the end of the shaft. If the speed limit does not operate below 20 per cent above normal speed the machine should be shut down and the reason found.

Circuit Opening

The device shown in Fig. 11 and 12 is of this type and consists essentially of a stationary and a moving part. The stationary part is a cast-iron shell (A) bolted to the end of the bearing housing, which carries two insulated contact clips (B) and a pivoted switch (C) provided with an insulated blade contact (D). The rotating part consists of a ring (E) keyed to the shaft (F) and a weight (H) pivoted on lugs (G) cast in the ring. The end of the weight is pulled toward the ring by a spiral spring (I) fastened to the ring. When the shaft revolves, the centrifugal force of the weight tends to move it outward, so that at a certain speed it swings outward until arrested by the hook-shaped stop cast on the ring (E). It then strikes link (J) forcing it outward and swinging the switch blade about the pivot (C).

This withdraws (D) from the contacts (B). The arrangement of the spring and weight is such that the action is positive; that is, as soon as the weight starts to move it swings out instantly against the stops operating the switch. The speed at which the switch operates may be controlled by an adjusting nut attached to the spiral spring. When the blade contact (D) is withdrawn from the contacts (B), the circuit through the low-voltage release coil on the circuit breaker is opened and the breaker tripped.

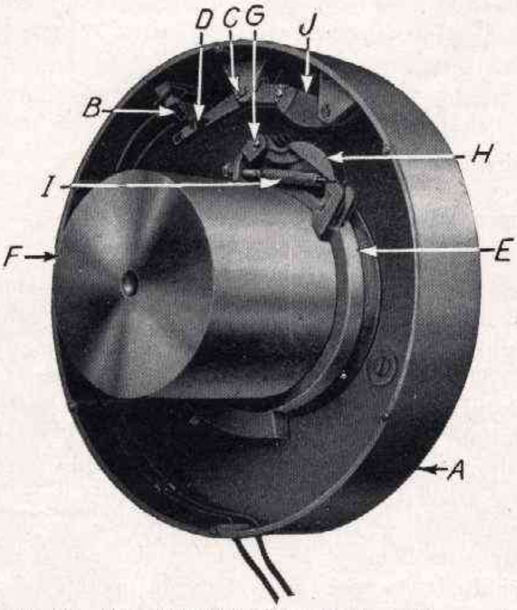

Fig. 12. Speed-limit Device with Cover Removed

Circuit Closing

The type of device which closes the circuit at overspeed is of the same general construction as shown in Fig. 11 and 12, the difference being in the length and details of the contact clips (B). The arrangement of these parts is such that at normal speed the switch blade is out of contact. At overspeed the blade is thrown into contact with the clips, thus closing the circuit to the shunt trip coil of the circuit breaker.

Circuit Opening and Closing

The type that has contacts for both opening and closing two circuits is essentially a combination of the two types just mentioned and is chiefly used on synchronous converters for automatic service.

Adjustment

For each type of device the adjustment requires that there be a minimum clearance of $\frac{1}{16}$ in. between the weight (H) and the link (J) when the weight is moved to its maximum outward position and the link has been operated either to open or to close the switch. This clearance is to prevent the weight hammering on the link after the switch has been operated.

With the switch blade in its open position and the weight in its maximum outward position there must be a minimum clearance of $\frac{3}{16}$ in. between the weight and blade.

With the switch in its normally operated position there must be a clearance of $\frac{1}{16}$ in. between weight and link.

When the blade of the circuit-opening device is open there must be a clearance of $\frac{1}{4}$ in. between the switch blade and its clips, and there must be a minimum clearance of $\frac{3}{16}$ in. between the nearest point of the switch blade and the weight (with weight in its maximum outward position).

See that the spring (I) is adjusted to permit the weight (H) to move outward and strike the link (J) when the machine reaches the specified speed limit.

STARTING UP

Initial Starting

Before starting the machine for the first time:

1. Flush out all bearings with oil in order to remove any grit or dirt that has accumulated during shipment. Do not use kerosene, for some of it may be left in pockets.

2. Fill the oil reservoirs with a good grade of lubricating oil to the oil-level line marked on the machine. When filling the thrust bearing, cloth strainers should be used at the discharge of the oil pipes to keep out dirt or scale that may be in the pipe line. Oil poured from barrels (even if new ones) directly into a bearing housing should also be poured through cloth strainers.

It is recommended that the oil have a viscosity of not less than 200 and not much over 300 (at 100 F) as determined by the Saybolt Universal Viscosimeter.

3. Examine the interior of the stator frame, the slip rings, the air gap, and the spaces between the poles for loose objects (bolts, nuts and tools). Use a magnet to remove all small metallic particles.

4. Make sure that all moving parts have sufficient clearance from the nearest stationary parts. Pay particular attention to the clearance between the pole faces and the stator.

5. Check the field winding for reversed polarity, uniformity of field-coil resistance, grounds, and open circuit.

The machine can then be started and run for some time at ⅓ speed, and bearing temperatures and shaft eccentricity checked. If the machine operates successfully it can be run at rated speed, and balanced if the vibration is excessive.

6. Turn on the bearing cooling water. The amount should be regulated after steady temperature conditions exist to obtain 10 to 15 C temperature rise when passing through the coils. It may be possible in some cases to cut down the water to a very small quantity, and even run without water when the temperature of the thrust-bearing oil bath is low.

Before putting the generator into service it is desirable to operate without load long enough to determine that there is no unusual localized heating.

DRYING OUT

Moisture in electric machines affects the insulation resistance of the windings and should be removed before the machine is placed in operation. It is usually found that machines which have not been exposed to rain or unusual dampness will not require drying out.

The following methods of drying out may be used:

Generators may be dried out by passing alternating or direct current through the windings, by operation at low voltage, or by use of external heat.

When drying out by use of alternating or direct current use 60 to 100 per cent of the normal current stamped on the nameplate. The current should be adjusted so that the temperature of the windings does not reach 90 C by resistance or embedded temperature detector (75 C by thermometer) in less than two hours, preferably in not less than six hours. The drying out should be continued at this temperature until the insulation resistance becomes constant.

Direct-current Method

When direct current is available the machine may be dried out stationary by applying the current separately to the stator and rotor. Do not use brushes to carry field current, but connect leads to copper bands clamped about the collector rings.

Alternating-current Method

Drive the machine at normal speed with all phases of the armature winding short-circuited. The field excitation should be just sufficient to produce an armature current which will give the temperatures mentioned above, but not more than 110 per cent of normal armature current.

Operation at Low Voltage

In case a low or variable a-c voltage is available the machine may be operated at 25 to 35 per cent rated voltage with the stator current adjusted to normal value or less by field control. The terminal voltage may be raised slowly as the drying progresses, or the machine may be operated at low voltage until the drying is completed and then placed in operation at normal voltage.

Use of External Heat

The external-heat method employs an oven or a number of coils of steam pipe, enclosed in a box with the machine. Openings in the top and bottom of the box should be provided to give ventilation, the moisture being carried off by the hot air. The temperature should not exceed 85 C.

Recirculating Air Systems

Machines having recirculating air systems should be vented during drying-out runs to remove excess moisture in the air.

Insulation Resistance

As a guide to determine whether sufficient moisture is present to require drying out, insulation-resistance measurements can be used; however, judgment should be exercised in using the values of resistance obtained. The insulation resistance of machinery is of doubtful significance as compared with the dielectric strength. It is subject to wide variation with temperature, humidity, and cleanliness of parts. When the insulation resistance falls below prescribed values it can in most cases be brought up to the required standard by cleaning and drying the machine. The insulation resistance therefore may afford a useful indication as to whether the machine is in suitable condition for application of the high-voltage test. The test for insulation resistance may be made as follows:

A direct-current voltmeter and a source of constant potential of 125 to 500 volts d-c are used. Before using power from any circuit for this test determine whether the supply circuit is grounded, by connecting to ground first one side and then the other through a single lamp for 125 volts or a bank of four lamps in series for 500 volts; if either side causes the lamps to light the circuit is grounded. The ungrounded side should be connected in series with a voltmeter to the windings of the machine and the grounded side to the frame of the machine being tested (see Fig. 13). The circuits should be protected with a fuse having a capacity of 5 to 10 amperes. An incandescent lamp may be substituted for the fuse if more convenient.

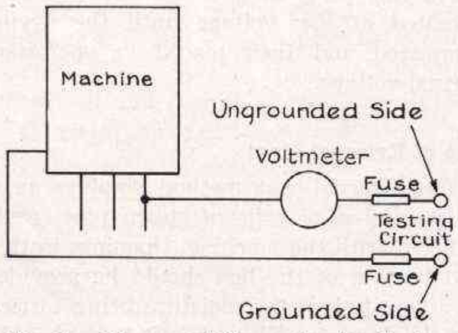

Fig. 13. Diagram of Connection for Testing Insulation Resistance

With the testing-circuit line switch open, read the voltage of the testing circuit. Then close the line switch and read the voltmeter connected between the ungrounded side of the line and the windings of the machines. The insulation resistance of the windings is then calculated from the following formula:

$$R_x = R_v\left(\frac{E}{E_1} - 1\right)$$

where E = voltage of d-c testing circuit,

E_1 = voltmeter reading when connected in series with the insulation resistance to be measured,

R_v = resistance of voltmeter in ohms,

R_x = insulation resistance in ohms.

In accordance with the ASA standards, the insulation resistance in megohms at approximately 75 C when the machine is clean and dry should be not less than

$$\frac{\text{Rated Voltage of Machine}}{\left(\frac{\text{Rating in Kva}}{100}\right) + 1000}$$

The insulation resistance of the rotor at 75 C should be in the order of ½ to 1 megohm.

PHASE SEQUENCE

The best method for testing phase sequence and at the same time checking the synchroscope connections is as follows: With the generator leads disconnected at the generator terminals, close the breaker. The synchroscope will indicate the position which the pointer will occupy when the generator is in synchronism. If the pointer is on the mark, the potential transformers and synchroscope are properly connected. If the pointer is at an angle, the connections are incorrect and should be changed.

A three-phase, fractional-horsepower motor or phase rotation indicator should be connected to the potential transformer on the generator side of the oil circuit breaker and the direction of rotation noted. The circuit breaker should then be opened and the generator leads temporarily connected. With the generator running and excited the direction of rotation of the motor or phase rotation meter is noted. If the phase rotation is the same in both cases, the generator leads can be permanently connected with complete assurance that the phase rotation and synchronizing connections are correct. If the phase rotation is incorrect, interchange any two of the three-phase terminal leads. For a two-phase generator interchange the two leads of either phase.

OPERATION

Starting (Generator Operating Singly)

1. See that all switches connecting the generator to any load are open.
2. Cut in all of the field resistance.
3. Start the machine and bring it up to speed.
4. Close the field switch and gradually cut out the field resistance until normal voltage is obtained.
5. Close the oil circuit breakers.
6. Apply the load gradually.
7. Turn on the cooling water.

Starting (Generator Operating in Parallel)

1. See that all switches connecting the incoming generator to any load are open.
2. Cut in all field resistance.
3. Start the generator and bring it up to speed under hand control of the driving unit.
4. Close the field switch and gradually cut out the field resistance until the voltage of the incoming generator is equal to that of the bus.
5. Vary the speed of the incoming generator until the voltage of the generator and bus are in phase (synchronized).
6. With the voltage of the generator and bus equal and in phase, close the oil circuit breaker.
7. Adjust the input to the generator by means of the driving unit to make the generator take its share of the load; adjust the field rheostat to give the proper value of field current. The approximate value of field current for rated load, voltage, and power factor is stamped on the nameplate.
8. Turn on the bearing cooling water.

When starting up after a temporary shutdown, it is unnecessary to wait for the machine to come to rest; as soon as the switches are open begin the regular order of starting operations.

Stopping

1. Adjust the input to the generator by means of the driving unit until the wattmeter indicates a light load.
2. Cut in the field resistance until the ammeter indicates a low value of current.
3. Trip the oil circuit breaker.
4. Apply the brakes at half speed.
5. When the generator comes to rest, open the field switch.
6. Shut off the bearing cooling water.

Low Voltage

The following causes may prevent generators from developing their normal voltage:

1. The speed of the generator may be below normal.
2. The switchboard instruments may be incorrect, and the voltage may be higher than that indicated, or the current may be greater than is shown by the readings.
3. The voltage of the exciter may be low because:
   (a) The speed is below normal.
   (b) The series field is reversed.
   (c) Part of its shunt field is reversed or short-circuited.
   (d) The brushes may be set incorrectly.
4. Part of the field rheostat or other unnecessary resistance may be in the field circuit.
5. The power factor of the load may be abnormally low.

INSPECTION AND MAINTENANCE

The generator should be inspected at least once a week and the following points given attention:

Cleanliness

The interior and exterior of the machine should be kept free from dirt, metallic particles, oil, and water. The machine should be cleaned as often as operating conditions make necessary.

Ventilating air should be kept as clean as possible. Dirt deposited on the windings and on the surfaces of the ventilating ducts of the core reduces the quantity of air passing through the machine and increases the temperature rise of the machine, thereby reducing the life of the insulation.

Compressed air is an effective means of cleaning the interior parts. Vacuum cleaners may be used on the windings, or the coils may be wiped clean with 50 per cent white gasoline, 50 per cent carbon tetrachloride, which is noninflammable and a less toxic mixture than pure carbon tetrachloride. When using cleaning fluids, provision should be made for removing the fumes from the pit or any pockets to prevent asphyxiation of the workmen. After cleaning, the coils should be sprayed with No. 183 and then No. 1202 air-drying varnish.

The collector rings, commutators, and brush rigging should be wiped carefully with dry lint-free cloths. Care should be taken to prevent cleaning fluids or the fumes contacting collector or commutator surfaces, since the surface films are sensitive to such fluids. Fine-grained stones may be used to remove pitted and rough spots from the collectors.

Bearings

See that the oil reservoirs are kept filled up to the oil level with a good grade of lubricating oil. The oil should be replaced about once in six months or oftener, depending on such conditions as cleanliness, severity or continuity of service, etc., and the bearings cleaned periodically. All the oil that is to be added should be first strained through cloth strainers.

Cooling coils should be checked for leaks periodically by applying air pressure to the coil to see if it will hold pressure for a period of time.

Cooling coils should also be cleaned regularly inside and outside. They may accumulate scale or sludge from hard or dirty water. Scale can be removed by a solution of equal parts of water and hydrochloric acid (muriatic acid). Some oils will deposit as sludge on the pipes.

Machines which are to be shut down for any length of time should have the water blown out of the cooling coils in case there is any danger of freezing.

Air Gap

Measure the air-gap clearance periodically with a gage to detect any change in alignment.

Bolts

All bolts should be inspected occasionally to see that they are tight, particular attention being given to the bolts used to clamp any insulation.

Bearing Insulation

A periodic check should be made of bearing insulation, and care taken to clean dirt pockets away from the insulation. The insulation should not be painted.

Insulation Resistance

Readings of winding-insulation resistance should be taken regularly, particularly during damp weather and after a long shutdown, for evidence of excessive moisture or dirt. If space heaters have been used during the shutdown, a dry-out run probably will not be necessary.

Rotors

The bolts, pole keys, and other fastenings on the rotor should be tightened securely when the machine is erected, checked after the equipment has run for a short time, and thereafter checked at regular intervals.

In case inspection of a rotor shows that there is looseness of pole-piece keys or bolts, a check should be made for evidence of damage due to this looseness. Such looseness may result in worn keys, damaged windings or chafed insulation. There will usually be sufficient stock for driving up the keys, but in some cases it may be necessary to drive out the keys and insert shims or to replace the old keys with new ones.

side of the oil circuit breaker and the direction of rotation noted. The circuit breaker should then be opened and the generator leads temporarily connected. With the generator running and excited the direction of rotation of the motor or phase rotation meter is noted. If the phase rotation is the same in both cases, the generator leads can be permanently connected with complete assurance that the phase rotation and synchronizing connections are correct. If the phase rotation is incorrect, interchange any two of the three-phase terminal leads. For a two-phase generator interchange the two leads of either phase.

OPERATION

Starting (Generator Operating Singly)

1. See that all switches connecting the generator to any load are open.
2. Cut in all of the field resistance.
3. Start the machine and bring it up to speed.
4. Close the field switch and gradually cut out the field resistance until normal voltage is obtained.
5. Close the oil circuit breakers.
6. Apply the load gradually.
7. Turn on the cooling water.

Starting (Generator Operating in Parallel)

1. See that all switches connecting the incoming generator to any load are open.
2. Cut in all field resistance.
3. Start the generator and bring it up to speed under hand control of the driving unit.
4. Close the field switch and gradually cut out the field resistance until the voltage of the incoming generator is equal to that of the bus.
5. Vary the speed of the incoming generator until the voltage of the generator and bus are in phase (synchronized).
6. With the voltage of the generator and bus equal and in phase, close the oil circuit breaker.
7. Adjust the input to the generator by means of the driving unit to make the generator take its share of the load; adjust the field rheostat to give the proper value of field current. The approximate value of field current for rated load, voltage, and power factor is stamped on the nameplate.
8. Turn on the bearing cooling water.

When starting up after a temporary shutdown, it is unnecessary to wait for the machine to come to rest; as soon as the switches are open begin the regular order of starting operations.

Stopping

1. Adjust the input to the generator by means of the driving unit until the wattmeter indicates a light load.
2. Cut in the field resistance until the ammeter indicates a low value of current.
3. Trip the oil circuit breaker.
4. Apply the brakes at half speed.
5. When the generator comes to rest, open the field switch.
6. Shut off the bearing cooling water.

Low Voltage

The following causes may prevent generators from developing their normal voltage:

1. The speed of the generator may be below normal.
2. The switchboard instruments may be incorrect, and the voltage may be higher than that indicated, or the current may be greater than is shown by the readings.
3. The voltage of the exciter may be low because:
   (a) The speed is below normal.
   (b) The series field is reversed.
   (c) Part of its shunt field is reversed or short-circuited.
   (d) The brushes may be set incorrectly.
4. Part of the field rheostat or other unnecessary resistance may be in the field circuit.
5. The power factor of the load may be abnormally low.

INSPECTION AND MAINTENANCE

The generator should be inspected at least once a week and the following points given attention:

Ordinarily two or three drivings will assure the keys' staying tight, but nevertheless they should be checked regularly.

Couplings

The alignment of couplings should be rechecked after the machine has been in operation a short time, to determine whether there has been any settling of the foundation or movement of the machine or the apparatus to which it is connected. After that, the alignment should be rechecked at regular intervals and corrected if necessary.

Foundation Caps

Foundation caps should also be checked periodically for evidence of lack of proper support due to foundation settling. On large machines the record of wye-level readings during installation can be used to check for nonuniform settling of the foundations.

Mechanical Balance

Generators should be checked regularly for any evidence of increase in unbalance both with and without the field current on.

TROUBLES

Frequent careful inspection of machines during operation is essential in order to detect any troubles which may in time result in a serious failure. Some of the troubles which should be looked for, and their causes, are given below. These troubles should be corrected as soon as discovered.

Machine Unbalanced

Any increase in machine vibration should be investigated immediately. If the vibration occurs without field on, check for evidence of misalignment, sprung shafting, or parts rubbing on the rotating element, before shifting any balance weights.

If the unbalance occurs only when field is on, check for grounds and also for short-circuited turns in the field windings. Poles with short-circuited field turns can be located by applying 110 volts a-c to the collector and measuring the pole-to-pole drop. Poles showing relatively low voltage drop have short-circuited turns.

Heating

Do not depend on the hand to determine temperatures; use a thermometer. If there is any doubt about the safe operating temperature, read the temperature of the part in question and confer with the nearest office of the General Electric Company. Give full details, including all nameplate information.

Hot bearings may be due to shaft currents because of defective bearing insulation; to misalignment; to worn-out, dirty, or insufficient oil; or to roughened bearing surfaces and, on guide bearings, to lack of proper clearance. When water-cooling coils are used, bearings may be hot because there is insufficient cooling water due to plugged or dirty coils.

Hot cores or windings may be due to excessive current, open or unbalanced phases, improper or insufficient ventilation, dirt, excessive ambient temperature, unequal air gap, short-circuited windings, and reversed field coil; on machines with air coolers, lack of cooling water.

TESTING

Generators which have been repaired after running in service should be given a high-potential test of one and one-half times normal voltage on the stator coils and 1000 volts on the field.

RENEWAL PARTS

When ordering renewal parts, state the quantity desired, the complete nameplate rating, and the serial number of the machine. Should any uncertainty exist as to exactly what is required, a sketch of the part wanted, giving all the necessary dimensions, should accompany the order. New parts for an accessory that is not made by the General Electric Company may be ordered direct from the manufacturer. When sending the order, give the data on the manufacturer's nameplate.

Store supply parts in a suitable place to prevent loss or damage. Slush all finished iron or steel surfaces with heavy oil or compound to protect them from corrosion.

when service is required

WHEN SERVICE IS REQUIRED

THE facilities of our engineering departments and factories are available to purchasers of G-E apparatus through G-E service shops and sales offices, a list of which is given below.

When it is necessary to renovate, repair, or change apparatus to meet a new operating condition or a new application, the facilities of the nearest G-E service shop are at your disposal. Each of them is equipped to turn out work of the same high quality, both as to workmanship and materials, as at the factory. If it is necessary that the work be done on the customer's premises, the service shop is prepared to send trained, competent, and dependable men who will do it promptly and efficiently. Similarly, the sales office nearest you will be glad to help you with any engineering problems that may be involved.

SERVICE SHOPS

Atlanta, Ga.	496 Glenn Street, Southwest
Buffalo, N. Y.	318 Urban Street
Charleston, W.Va.	306 MacCorkle Avenue, Southeast
Chicago, Ill.	849 South Clinton Street
Cincinnati, Ohio	215 West Third Street
Cleveland, Ohio	4966 Woodland Avenue
Dallas, Texas	1801 North Lamar Street
Detroit, Mich.	5950 Third Avenue
Houston, Texas	1312 Live Oak Street
Kansas City, Mo.	819 East Nineteenth Street
Los Angeles, Calif.	733 Banning Street
Milwaukee, Wis.	940 West St. Paul Avenue
Minneapolis, Minn.	410 Third Avenue, North
New York, N. Y.	416 West Thirteenth Street
Philadelphia, Pa.	429 North Seventh Street
Pittsburgh, Pa.	6519 Penn Avenue
St. Louis, Mo.	1110 Delmar Boulevard
Salt Lake City, Utah	141 South Third West Street
San Francisco, Calif.	361 Bryant Street
Seattle, Wash.	1508 Fourth Avenue, South
West Lynn, Mass.	920 Western Avenue

Special service divisions are also maintained at the following Works of the Company: Erie, Pa.; Ft. Wayne, Ind.; Pittsfield, Mass.; Schenectady, N. Y.; and West Lynn, Mass. (West Lynn Works)

SALES OFFICES (Address nearest office)

Akron, Ohio	335 South Main Street
Atlanta, Ga.	187 Spring Street, Northwest
Baltimore, Md.	39 West Lexington Street
Bangor, Me.	115 Franklin Street
Beaumont, Texas	398 Pearl Street
Binghamton, N. Y.	19 Chenango Street
Birmingham, Ala.	600 North Eighteenth Street
Bluefield, W. Va.	Appalachian Building
Boston, Mass.	140 Federal Street
Buffalo, N. Y.	1 West Genesee Street
Butte, Mont.	20 West Granite Street
Cedar Rapids, Iowa	203 Second Street, Southeast
Charleston, W. Va.	306 MacCorkle Avenue, Southeast
Charlotte, N. C.	200 South Tryon Street
Chattanooga, Tenn.	832 Georgia Avenue
Chicago, Ill.	840 South Canal Street
Cincinnati, Ohio	215 West Third Street
Cleveland, Ohio	4966 Woodland Avenue
Columbus, Ohio	40 South Third Street
Dallas, Texas	1801 North Lamar Street
Davenport, Iowa	511 Pershing Avenue
Dayton, Ohio	25 North Main Street
Denver, Colo.	650 Seventeenth Street
Des Moines, Iowa	418 West Sixth Avenue
Detroit, Mich.	700 Antoinette Street
Duluth, Minn.	14 West Superior Street
El Paso, Texas	109 North Oregon Street
Erie, Pa.	10 East Twelfth Street
Evansville, Ind.	123 Northwest Fourth Street
Fairmont, W. Va.	511 Jacobs Building
Fort Wayne, Ind.	127 West Berry Street
Fort Worth, Texas	408 West Seventh Street
Grand Rapids, Mich.	148 Monroe Avenue, Northwest
Hartford, Conn.	410 Asylum Street
Houston, Texas	1312 Live Oak Street
Indianapolis, Ind.	110 North Illinois Street
Jackson, Mich.	212 Michigan Avenue, West
Jacksonville, Fla.	237 West Forsyth Street
Kansas City, Mo.	106 West Fourteenth Street
Knoxville, Tenn.	602 South Gay Street
Los Angeles, Calif.	212 North Vignes Street
Louisville, Ky.	455 South Fourth Street
Memphis, Tenn.	8 North Third Street
Milwaukee, Wis.	940 West St. Paul Avenue
Minneapolis, Minn.	12 South Sixth Street
Nashville, Tenn.	234 Third Avenue, North
Newark, N. J.	744 Broad Street
New Haven, Conn.	129 Church Street
New Orleans, La.	837 Gravier Street
New York, N. Y.	570 Lexington Avenue
Niagara Falls, N. Y.	253 Second Street
Oakland, Calif.	1648 Sixteenth Street
Oklahoma City, Okla.	119 North Robinson Street
Omaha, Nebr.	409 South Seventeenth Street
Philadelphia, Pa.	1405 Locust Street
Phoenix, Ariz.	435 West Madison Street
Pittsburgh, Pa.	535 Smithfield Street
Portland, Me.	477 Congress Street
Portland, Ore.	920 Southwest Sixth Avenue
Providence, R. I.	111 Westminster Street
Reading, Pa.	31 North Sixth Street
Richmond, Va.	700 East Franklin Street
Roanoke, Va.	202 South Jefferson Street
Rochester, N. Y.	89 East Avenue
St. Louis, Mo.	112 North Fourth Street
Salt Lake City, Utah	200 South Main Street
San Antonio, Texas	310 South St. Mary's Street
San Diego, Calif.	861 Sixth Avenue
San Francisco, Calif.	235 Montgomery Street
Schenectady, N. Y.	202 State Street
Seattle, Wash.	710 Second Avenue
Spokane, Wash.	421 Riverside Avenue
Springfield, Ill.	607 East Adams Street
Springfield, Mass.	1387 Main Street
Syracuse, N. Y.	113 South Salina Street
Tacoma, Wash.	1019 Pacific Avenue
Toledo, Ohio	420 Madison Avenue
Tulsa, Okla.	409 South Boston Street
Utica, N. Y.	258 Genesee Street
Washington, D. C.	806 Fifteenth Street, Northwest
Waterbury, Conn.	95 North Main Street
Wichita, Kan.	102 South Broadway
Worcester, Mass.	165 Commercial Street
Youngstown, Ohio	25 East Boardman Street

Canada: Canadian General Electric Company, Ltd., Toronto

Hawaii: W. A. Ramsay, Ltd., Honolulu

G-E products can also be obtained through Agents and Distributors located in principal cities and towns ①

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